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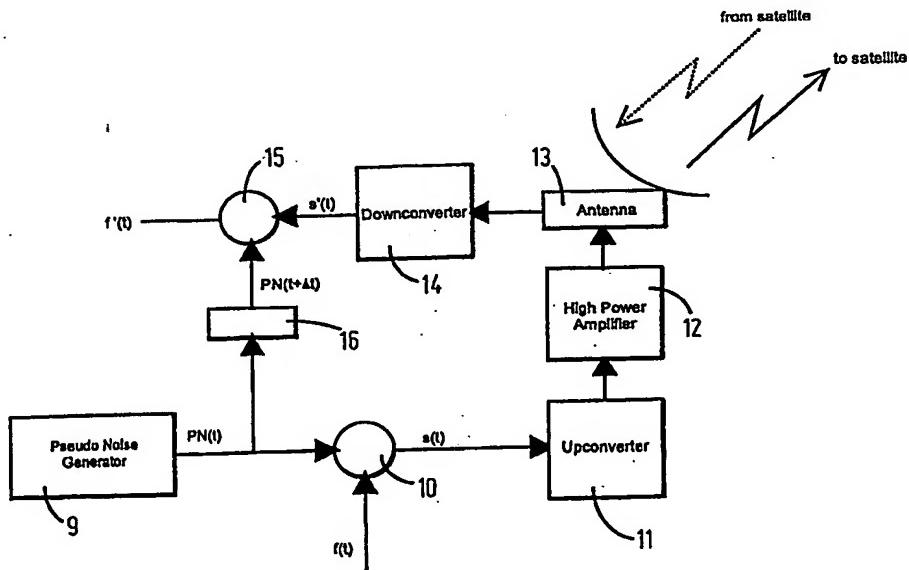
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(71) Applicant: SOCIETE EUROPEENNE DES SATELLITES S.A. [LU/LU]; L-6815 Château de Betzdorf (LU).		
(72) Inventors: BETHSCHEIDER, Gerhard; Wiesenweg 12, D-54441 Ayl (DE). HARLES, Guy; 48A, rue du 9 mai 1944, L-2112 Howald (LU).		
(74) Agents: ZANGS, Rainer et al.; Hoffmann . Eitle, Arabellasstrasse 4, D-81925 Munich (DE).		

(54) Title: METHOD AND APPARATUS FOR DETERMINING CHARACTERISTICS OF COMPONENTS OF A COMMUNICATION CHANNEL UNDER LOAD



(57) Abstract

For determining characteristics of components of a communication channel, for example of a transponder in a communication satellite, a clean carrier signal $f(t)$ is modulated with a pseudo noise signal $PN(t)$ and transmitted through the communication channel at a level below the level of a payload signal which is transmitted via the communication channel simultaneously. The received signal $s'(t)$ is correlated with same pseudo noise signal $PN(t)$ to obtain a recovered carrier signal $f'(t)$. Both the clean carrier signal $f(t)$ and the recovered carrier signal $f'(t)$ can be used to determine the desired characteristics. Since the PN modulated clean carrier signal $s(t)$ is transmitted at a low level, it is possible to perform measurements without switching off the payload signal.

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5 Method and apparatus for determining characteristics of
components of a communication channel under load

10 This invention relates to a method and an apparatus for
determining characteristics of components of a
communication channel, especially a transponder in a
communication satellite under load.

15 The characteristics of a communication channel may change
during the lifetime of the equipment used. Various tests
may be performed not only at the beginning of but also
repeatedly during the lifetime to verify that the
communication channel meets predetermined specifications.
Usually, these tests are performed without normal traffic,
i.e. without the communication channel being used for
20 transmission of a communication signal. This scenario will
be explained in the following in greater detail with
reference to communication satellites but without limiting
the invention disclosed further below to only this
application although the invention is specifically
25 applicable in this field.

30 In a communication satellite, a communication channel is
set up by a transponder of the satellite comprising several
components like a receiving antenna, an input
demultiplexer, a power amplifier, an output multiplexer,
and a transmitting antenna. Transponder characteristics,
such as amplitude response and group delay, are measured
not only at the beginning of life of the spacecraft on the
ground and, after launch, in orbit but also during the
35 lifetime. These measurements are conventionally carried out
without normal traffic on the transponder, i.e. without a

payload signal being transmitted to and being re-transmitted by the transponder.

- 5 The necessity of switching off the payload signal during tests represents a considerable drawback not only for the user of the transponder, since communication is interrupted, but also for the operator of the satellite since the tests have to be performed in an expedited manner to keep the interruption as short as possible. In some
10 cases it is impossible to interrupt communications via the communication channel so that the components of these channels cannot be tested after having entered into operation.
- 15 It is an object of the present invention to provide a method and an apparatus for determining characteristics of components of a communication channel, especially a transponder of a satellite, without the necessity to interrupt traffic via the communication channel.
20
- This object and other objects are achieved by a method for determining characteristics of components of a communication channel through which a payload signal is transmitted at a predetermined level, comprising:
25 generating a first pseudo noise signal $PN(t)$; modulating a clean carrier signal $f(t)$ with said first pseudo noise signal $PN(t)$ to generate a PN modulated clean carrier signal $s(t)$; transmitting said PN modulated clean carrier signal $s(t)$ simultaneously with said payload signal through
30 said communication channel at a level below the level of said payload signal; receiving a receive signal $s'(t)$ corresponding to said PN modulated clean carrier signal $s(t)$ after having traveled through said communication channel; correlating said receive signal $s'(t)$ with said
35 first pseudo noise signal $PN(t)$ to generate a recovered carrier signal $f'(t)$; and determining characteristics of components of the communication channel on the basis of a

comparison of said clean carrier signal $f(t)$ and said recovered carrier signal $f'(t)$.

Advantageously, the level of said PN modulated clean carrier signal $s(t)$ is at least 15 dB, preferably 25 dB or more below the level of said payload signal.

In a further embodiment, said first pseudo noise signal $PN(t)$ is a binary pseudo noise sequence, which is 10 preferably generated by means of a feed back shift register.

A chiprate of said first pseudo noise signal $PN(t)$ is less than 5 MChip/s and preferably less than or equal to 2,5 15 MChip/s.

In a further embodiment, said correlating of said receive signal $s'(t)$ and said first pseudo noise signal $PN(t)$ is achieved by delaying said first pseudo noise signal $PN(t)$ 20 and multiplying the delayed first pseudo noise signal $PN(t)$ and said receive signal $s'(t)$.

To generate a reference, the method according to the invention further comprises: generating a second pseudo noise signal $PN_R(t)$; modulating a reference carrier signal $f_R(t)$ with said second pseudo noise signal $PN_R(t)$ to generate a PN modulated reference carrier signal $s_R(t)$; transmitting said PN modulated reference carrier signal $s_R(t)$ simultaneously with said payload signal through said communication channel at a level below the level of said payload signal; receiving a reference receive signal $s_R'(t)$ corresponding to said PN modulated reference carrier signal $s_R(t)$ after having traveled through said communication channel; correlating said reference receive signal $s_R'(t)$ 35 with said second pseudo noise signal $PN_R(t)$ to generate a recovered reference carrier signal $f_R'(t)$; and determining characteristics of components of the communication channel

also on the basis of a comparison of said reference carrier signal $f_R(t)$ and said recovered carrier signal $f_R'(t)$.

Advantageously, the level of said PN modulated reference carrier signal $s_R(t)$ is at least 15 dB, preferably 25 dB or more below the level of said payload signal.

In a further embodiment, said second pseudo noise signal $PN(t)$ is a binary pseudo noise sequence which is preferably generated by means of a feed back shift register.

In a further embodiment, said correlating of said reference receive signal $s_R'(t)$ and said second pseudo noise signal $PN_R(t)$ is achieved by delaying said second pseudo noise signal $PN_R(t)$ and multiplying the delayed second pseudo noise signal $PN_R(t)$ and said reference receive signal $s_R'(t)$.

The method of the invention as characterized above is especially applicable when said communication channel is a transponder of a communication satellite. Said PN modulated reference signal $s_R(t)$ may be transmitted through the same transponder of the satellite, but then said second pseudo noise signal $PN_R(t)$ must not correlated with said pseudo noise signal $PN(t)$. Said PN modulated reference signal $s_R(t)$ can also be transmitted through a different transponder of the satellite.

The characteristics of said communication channel may be group delay and amplitude response.

The above objects and other objects are also achieved by an apparatus for determining characteristics of components of a communication channel through which a payload signal is transmitted at a predetermined level, comprising first pseudo noise signal generating means for generating a pseudo noise signal $PN(t)$; first modulating means for

modulating a clean carrier signal $f(t)$ with said first pseudo noise signal $PN(t)$ to generate a PN modulated clean carrier signal $s(t)$; transmitting means for transmitting said PN modulated clean carrier signal $s(t)$ simultaneously with said payload signal through said communication channel at a level below the level of said payload signal; receiving means for receiving a receive signal $s'(t)$ corresponding to said PN modulated clean carrier signal $s(t)$ after having traveled through said communication channel; and first correlating means for correlating said receive signal $s'(t)$ with said pseudo noise signal $PN(t)$ to generate a recovered carrier signal $f'(t)$.

Advantageously, the level of said PN modulated clean carrier signal $s(t)$ is at least 15 dB, preferably 25 dB or more below the level of said payload signal.

In a further embodiment, said first pseudo noise signal generating means is a feed back shift register.

A chiprate of said first pseudo noise signal $PN(t)$ is less than 5 MChip/s preferably less than or equal to 2,5 MChip/s.

In a further embodiment, the above apparatus comprises first delaying means for delaying said first pseudo noise signal $PN(t)$.

To obtain a reference, the above apparatus further comprises second pseudo noise generating means for generating a second pseudo noise signal $PN_R(t)$; second modulating means for modulating a reference carrier signal $f_R(t)$ with said second pseudo noise signal $PN_R(t)$ to generate a PN modulated reference carrier signal $s_R(t)$; transmitting means for transmitting said PN modulated reference carrier signal $s_R(t)$ simultaneously with said payload signal through said communication channel at a

level below the level of said payload signal; receiving means for receiving a reference receive signal $s_R'(t)$ corresponding to said PN modulated reference carrier signal $s_R(t)$ after having traveled through said communication

5 channel; and second correlating means for correlating said reference receive signal $s_R'(t)$ with said second pseudo noise signal $PN_R(t)$ to generate a recovered reference carrier signal $f_R'(t)$.

10 Advantageously, the level of said PN modulated reference carrier signal $s(t)$ is at least 15 dB, preferably 25 dB or more below the level of said payload signal.

15 In a further embodiment, said second pseudo noise signal generating means is a feed back shift register.

In a further embodiment, the above apparatus further comprises second delaying means for delaying said second pseudo noise signal $PN_R(t)$.

20 In summary, for determining characteristics of components of a communication channel, for example of a transponder in a communication satellite, a clean carrier signal $f(t)$ is modulated with a pseudo noise signal $PN(t)$ and transmitted
25 through the communication channel at a level below the level of a payload signal which is transmitted via the communication channel simultaneously. The received signal $s'(t)$ is correlated with the same pseudo noise signal $PN(t)$ to obtain a recovered carrier signal $f'(t)$. The clean
30 carrier signal $f(t)$ and the recovered carrier signal $f'(t)$ are used together to determine the desired characteristics. Since the PN modulated clean carrier signal $s(t)$ is transmitted at a low level, it is possible to perform measurements without switching off the payload signal.

35 The most important advantage of the method and the apparatus according to the invention is of course that the

payload signal does not have to be switched off for performing the measurements. This limits considerably the downtime required for maintenance and verification of the communication channel, and thus increases availability of
5 services.

Another very important advantage is the fact that with this method and apparatus, it is possible to measure characteristics of components of the communication channel
10 under realistic conditions. For example, in a satellite transponder the IMUX and OMUX filters are waveguide filters and the characteristics of these filters are changing with the temperature. Normally, the filters are not uniformly heated during operation but are heated depending on the
15 payload signal. When the payload signal is switched off the temperature distribution changes compared to normal operation even if the test signals provide a certain power for heating the filters. Thus, with conventional methods characteristics cannot be determined under conditions
20 present in the communication channel under load. In addition, in the proposed method the spectral power density of the measurement signal is considerably lower than the spectral power density of the payload signal, so that it is possible to characterise the behaviour of the
25 communications channel under the most realistic circumstances.

A further advantage of the invention is that in the case of a satellite communication channel the conversion frequency
30 of the uplink/downlink can be measured without interruption of the payload signal and simultaneously with the other measurements.

In the following an embodiment of the invention will be
35 described in greater detail and with reference to the drawings.

Fig. 1 shows a schematic diagram of a transponder of a communication satellite;

5 Fig. 2 shows a schematic diagram of a first embodiment of an apparatus according to the invention;

Fig. 3a and 3b show diagrams representing measurement result;

10 Fig. 4 shows a schematic diagram of a second embodiment of an apparatus according to the invention.

For the purpose of describing an embodiment of the invention, Fig. 1 shows the components of a transponder in 15 a communication satellite as an example for a communication channel.

A transponder of a communication satellite comprises a receiving antenna 1 for receiving an uplink signal send 20 from a ground station (not shown). An output signal of said receiving antenna 1 is fed to an input demultiplexer (IMUX) 3 after frequency conversion in frequency converter 2. Said input demultiplexer 3 comprises several first filters 4-1 to 4-n for separating individual signals within the signal 25 from the antenna. Typically, one filter is provided for each signal to be separated from the other signals received via said receiving antenna 1 and corresponds to a communication channel. The n output signals of said input demultiplexer 3 are fed to a corresponding number of high 30 power amplifiers 5-1 to 5-n in each of which a traveling wave tube (TWT) is employed for amplifying the output signals of said input demultiplexer 3. As each of said high power amplifiers is normally operated in its saturation point, multiple signals would create intermodulation 35 products and distortion of the signals. The amplifier output signals are passed through second filters 6-1 to 6-n which are part of an output multiplexer (OMUX) 7 combining

the n amplifier output signals. The output signal of said output multiplexer 7 is fed to a transmitting antenna 8 for being transmitted to the desired area on the ground.

- 5 Since the filters provided in the input demultiplexer (IMUX) 3 and the output multiplexer (OMUX) 7 have a strong influence on the performance of the transponder, the method according to the invention will be explained in following with respect to measuring two specific characteristics,
- 10 namely amplitude response and group delay, of these components of the transponder communication channels, the method of the invention being especially suitable for this application. However, the same or other characteristics of other components of the communication channel can be
- 15 determined by means of the method and the apparatus according to the invention.

According to the invention, in a ground station as shown in Fig. 2, a pseudo noise signal $PN(t)$ is generated by means 20 of a pseudo noise signal generator 9, for example, a feed back shift register or a memory device in which a sequence of values of a pseudo noise signal is stored. The pseudo noise signal $PN(t)$ has a very sharp autocorrelation function at zero delay. This allows to determine the time 25 delay between the locally generated pseudo noise signal $PN(t)$ and a received signal which is delayed due to the propagation time. A clean carrier signal $f(t)$ having a variable frequency, which is changed as explained further below, is modulated with said pseudo noise signal $PN(t)$ by 30 means of a first multiplier 10 to form a PN modulated clean carrier signal $s(t) = PN(t) \times f(t)$. The chiprate of the pseudo noise signal $PN(t)$, which determines the bandwidth of this signal, is chosen such the bandwidth of the PN modulated clean carrier signal $s(t)$ is narrow in comparison 35 with the expected peaks in group delay of the communication channel. Typically, the chiprate of the pseudo noise signal may be chosen less than 5 MChip/s.

The PN modulated clean carrier signal $s(t)$ is fed to an upconverter 11 and via a high power amplifier 12 to an antenna 13 which transmits the PN modulated clean carrier signal $s(t)$ to the transponder of the communication satellite under test. However, from the viewpoint of a user transmitting a payload signal to the satellite, the transponder remains usable during the test and can be continuously supplied with a payload signal.

10

According to the invention, the level of the transmitted PN modulated clean carrier signal $s(t)$ is sufficiently below the level of the payload signal, for example about 15 to 25 dB or more, such that the payload signal is not notably deteriorated. For this reason, the PN modulated clean carrier signal $s(t)$ can be transmitted while the communication channel is in use, i.e. simultaneously with a payload signal being transmitted to the transponder of the satellite from the same or from another ground station.

15

The frequency of the clean carrier signal $f(t)$ is changed such that it sweeps from the lowest to the highest frequency of the pass band of the filters in the satellite transponder, or any other component of a general communication channel under test. The PN modulated clean carrier signal $s(t)$ has a narrow bandwidth due to the pseudo noise signal $PN(t)$ such that amplitude response and group delay of the communication channel can be determined at selected discrete frequencies, as will be described in 20
30 the following.

In the embodiment, antenna 13 is also used to receive the signal re-transmitted by the transponder of the satellite, in other words the signal which has traveled through the communication channel. The output signal of antenna 13 is passed through a downconverter 14 to obtain a receive signal $s'(t)$ which is fed to a second multiplier 15

receiving also the same but delayed pseudo noise signal PN(t). The delay is generated by delaying means 16 which are set such that the output of the second multiplier 15 becomes maximal. Thereby, the receive signal s'(t) is multiplied, in other words correlated with the very same pseudo noise signal PN(t) which has been used for generating the PN modulated clean carrier signal s(t) and a recovered carrier signal f'(t) is obtained which is only delayed and attenuated in comparison with the clean carrier signal f(t). Thus, the amplitude response, which corresponds to the attenuation of the recovered carrier signal f'(t), and the group delay, which corresponds to the delay of the recovered carrier signal f'(t), of the transponder of the satellite, as an example of a general communication channel, can easily be determined. The runtime of a narrowband signal at its center frequency corresponds to the group delay of the filters if the phase can be linearly approximated in the signal bandwidth. The chiprate of the PN signal is determined accordingly.

As far as communication satellites are concerned, it is sufficient to determine the amplitude response and group delay over the pass band of a transponder only relative to the amplitude response and group delay at the center frequency of the pass band. Therefore, it is sufficient to delay the pseudo noise signal PN(t) such that the amplitude of the recovered carrier signal f'(t) becomes maximal and to subtract the amplitude and the delay at the center frequency from the amplitude and the delay at any other frequency in the pass band, respectively.

Fig. 3a and 3b show typical measurement result for amplitude response (Fig. 3a) and group delay (Fig. 3b) as obtained by the method according to the invention.

In the case of a satellite communication channel, i.e. a transponder, it should be noted that, during measurements,

due to the movements of the satellite the distance to the satellite can change. Also, during measurements, due to atmospheric effects the attenuation of the path loss between the ground station and the satellite can change.

5 Since in the above embodiment the amplitude response and the group delay is determined by subtracting the amplitude response and the group delay at the center frequency from the respective values at other discrete frequencies, an error might occur due to the before mentioned satellite

10 movements and atmospheric effects or other influences.

As shown in Fig. 4, a reference signal $s_R(t)$ can be used to compensate the before mentioned measurement error. In Fig. 4 the same reference signals are used for those parts already

15 described above and reference is made to the above description of these parts. The reference signal $s_R(t)$ is generated by means of a third multiplier 18 which receives a second pseudo noise signal $PN_R(t)$, which is not correlated with the first pseudo noise signal $PN(t)$ and

20 which is generated by a second pseudo noise generator 17, and a reference carrier signal $f_R(t)$ which may be located at a fixed frequency somewhere within the pass band of the same transponder or in the pass band of another transponder on the same satellite having a different center frequency.

25 Like in the above embodiment, a PN modulated reference carrier signal $s_R(t)$ is transmitted to the satellite and the reference receive signal $s_R'(t)$ is multiplied with the second pseudo noise signal $PN_R(T)$ to obtain the recovered reference signal $f_R'(t)$. While the measurement signal is

30 swept in frequency over the transponder pass band, the frequency of the reference carrier signal $f_R(t)$ remains at a fixed frequency. Therefore, a corrected amplitude response and group delay of the communications channel can be obtained by subtracting the values of the reference

35 signal from the values of the measurement signals at the respective time.

A variation of the described measuring the group delay consists of measuring the phase of the reconstructed carrier of the PN modulated signal at a specified frequency very close to the first frequency, it is possible to 5 approximate the group delay at the frequency located in the middle of both measurement frequencies by calculating the phase difference and dividing by the frequency difference.

Only pseudo noise signals have been discussed above because 10 these signals can be generated comparatively easily. However, true noise signals can be used in the method and the apparatus according to the invention. Properties of true and pseudo noise signals are well known to those skilled in the art and are described, for example in 15 Bernard Sklar, "Digital Communications - Fundamentals and Applications", Prentice Hall, 1988.

Claims

1. Method for determining characteristics of components of a communication channel through which a payload signal is transmitted at a predetermined level, comprising:
 - generating a first pseudo noise signal $PN(t)$;
 - modulating a clean carrier signal $f(t)$ with said first pseudo noise signal $PN(t)$ to generate a PN modulated clean carrier signal $s(t)$;
 - transmitting said PN modulated clean carrier signal $s(t)$ simultaneously with said payload signal through said communication channel at a level below the level of said payload signal;
 - receiving a receive signal $s'(t)$ corresponding to said PN modulated clean carrier signal $s(t)$ after having traveled through said communication channel;
 - correlating said receive signal $s'(t)$ with said first pseudo noise signal $PN(t)$ to generate a recovered carrier signal $f'(t)$; and
 - determining characteristics of components of the communication channel on the basis of a comparison of said clean carrier signal $f(t)$ and said recovered carrier signal $f'(t)$.
2. Method according to claim 1, wherein the level of said PN modulated clean carrier signal $s(t)$ is at least 15 dB below the level of said payload signal.
3. Method according to claim 2, wherein the level of said PN modulated clean carrier signal $s(t)$ is at least 25 dB below the level of said payload signal.
4. Method according to any one of claims 1 to 3, wherein said first pseudo noise signal $PN(t)$ is a binary pseudo noise sequence.

5. Method according to claim 4, wherein said binary pseudo noise sequence is generated by means of a feed back shift register or a memory device in which a sequence of values of a pseudo noise signal is stored.
- 5
6. Method according to any one of claims 1 to 5, wherein a chiprate of said first pseudo noise signal $PN(t)$ is less than 5 MChip/s.
- 10 7. Method according to claim 6, wherein a chiprate of said first pseudo noise signal $PN(t)$ is less than or equal to 2,5 MChip/s.
- 15 8. Method according to any one of claims 1 to 7, wherein said correlating of said receive signal $s'(t)$ and said first pseudo noise signal $PN(t)$ is achieved by delaying said first pseudo noise signal $PN(t)$ and multiplying the delayed first pseudo noise signal $PN(t)$ and said receive signal $s'(t)$.
- 20 9. Method according to any one of claims 1 to 8, further comprising:
 - generating a second pseudo noise signal $PN_R(t)$;
 - modulating a reference carrier signal $f_R(t)$ with said second pseudo noise signal $PN_R(t)$ to generate a PN modulated reference carrier signal $s_R(t)$;
 - 25 - transmitting said PN modulated reference carrier signal $s_R(t)$ simultaneously with said payload signal through said communication channel at a level below the level of said payload signal;
 - receiving a reference receive signal $s_R'(t)$ corresponding to said PN modulated reference carrier signal $s_R(t)$ after having traveled through said communication channel;
 - 30 - correlating said reference receive signal $s_R'(t)$ with said second pseudo noise signal $PN_R(t)$ to
- 35

- generate a recovered reference carrier signal $f_R'(t)$;
and
- determining characteristics of components of the communication channel also on the basis of a
5 comparison of said reference carrier signal $f_R(t)$ and said recovered carrier signal $f_R'(t)$.
10. Method according to claim 9, wherein the level of said PN modulated reference carrier signal $s_R(t)$ is at least 15 dB below the level of said payload signal.
10. Method according to claim 10, wherein the level of said PN modulated reference carrier signal $s_R(t)$ is at least 25 dB below the level of said payload signal.
15. Method according to any one of claims 9 to 11, wherein said second pseudo noise signal $PN(t)$ is a binary pseudo noise sequence.
20. Method according to claim 12, wherein said binary pseudo noise sequence is generated by means of a feed back shift register or a memory device in which a sequence of values of a pseudo noise signal is stored.
25. Method according to any one of claims 9 to 13, wherein said correlating of said reference receive signal $s_R'(t)$ and said second pseudo noise signal $PN_R(t)$ is achieved by delaying said second pseudo noise signal $PN_R(t)$ and multiplying the delayed second pseudo noise signal $PN_R(t)$ and said reference receive signal $s_R'(t)$.
30. Method according to any one of claims 1 to 14, wherein said communication channel is a transponder of a communication satellite.

16. Method according to claims 14 and 15, wherein said PN modulated reference signal $s_R(t)$ is transmitted through the same transponder of the satellite and said second pseudo noise signal $PN_R(t)$ not correlated with said pseudo noise signal $PN(t)$.
5
17. Method according to claims 14 and 15, wherein said PN modulated reference signal $s_R(t)$ is transmitted through a different transponder of the satellite.
10
18. Method according to any one of claims 1 to 17, wherein one of the characteristics of said communication channel is group delay and / or amplitude response.
15
19. Apparatus for determining characteristics of components of a communication channel through which a payload signal is transmitted at a predetermined level, comprising:
 - first pseudo noise signal generating means (9) for generating a pseudo noise signal $PN(t)$;
 - first modulating means (10) for modulating a clean carrier signal $f(t)$ with said first pseudo noise signal $PN(t)$ to generate a PN modulated clean carrier signal $s(t)$;
 - transmitting means (11, 12, 13) for transmitting said PN modulated clean carrier signal $s(t)$ simultaneously with said payload signal through said communication channel at a level below the level of said payload signal;
25
 - receiving means (13, 14) for receiving a receive signal $s'(t)$ corresponding to said PN modulated clean carrier signal $s(t)$ after having traveled through said communication channel; and
 - first correlating means (14) for correlating said receive signal $s'(t)$ with said pseudo noise signal $PN(t)$ to generate a recovered carrier signal $f'(t)$.
30

20. Apparatus according to claim 19, wherein the level of said PN modulated clean carrier signal $s(t)$ is at least 15 dB below the level of said payload signal.
- 5 21. Apparatus according to claim 20, wherein the level of said PN modulated clean carrier signal $s(t)$ is at least 25 dB below the level of said payload signal.
- 10 22. Apparatus according to any one of claims 19 to 21, wherein said first pseudo noise signal generating means (9) is a feed back shift register or a memory device in which a sequence of values of a pseudo noise signal is stored.
- 15 23. Apparatus according to any one of claims 19 to 22, wherein a chiprate of said first pseudo noise signal $PN(t)$ is less than 5 MChip/s.
- 20 24. Apparatus according to claim 23, wherein a chiprate of said first pseudo noise signal $PN(t)$ is less than or equal to 2,5 MChip/s.
- 25 25. Apparatus according to any one of claims 19 to 24, further comprising first delaying means (16) for delaying said first pseudo noise signal $PN(t)$.
26. Apparatus according to any one of claims 19 to 25, further comprising
 - second pseudo noise generating means (17) for generating a second pseudo noise signal $PN_R(t)$;
 - second modulating means (18) for modulating a reference carrier signal $f_R(t)$ with said second pseudo noise signal $PN_R(t)$ to generate a PN modulated reference carrier signal $s_R(t)$;
 - transmitting means (11, 12, 13) for transmitting said PN modulated reference carrier signal $s_R(t)$ simultaneously with said payload signal through said

- communication channel at a level below the level of said payload signal;
- receiving means (13, 14) for receiving a reference receive signal $s_R'(t)$ corresponding to said PN modulated reference carrier signal $s_R(t)$ after having traveled through said communication channel;
 - 5 and
 - second correlating means (20) for correlating said reference receive signal $s_R'(t)$ with said second pseudo noise signal $PN_R(t)$ to generate a recovered reference carrier signal $f_R'(t)$.
- 10
27. Apparatus according to claim 26, wherein the level of said PN modulated reference carrier signal $s(t)$ is at least 15 dB below the level of said payload signal.
- 15
28. Apparatus according to claim 27, wherein the level of said PN modulated reference carrier signal $s(t)$ is at least 25 dB below the level of said payload signal.
- 20
29. Apparatus according to any one of claims 26 to 28, wherein said second pseudo noise signal generating means (9) is a feed back shift register or a memory device in which a sequence of values of a pseudo noise signal is stored.
- 25
30. Apparatus according to any one of claims 29 to 34, further comprising second delaying means (19) for delaying said second pseudo noise signal $PN_R(t)$.
- 30
31. Apparatus according to any one of claims 19 to 30, wherein one of the characteristics of said communication channel is group delay and / or amplitude response.
- 35

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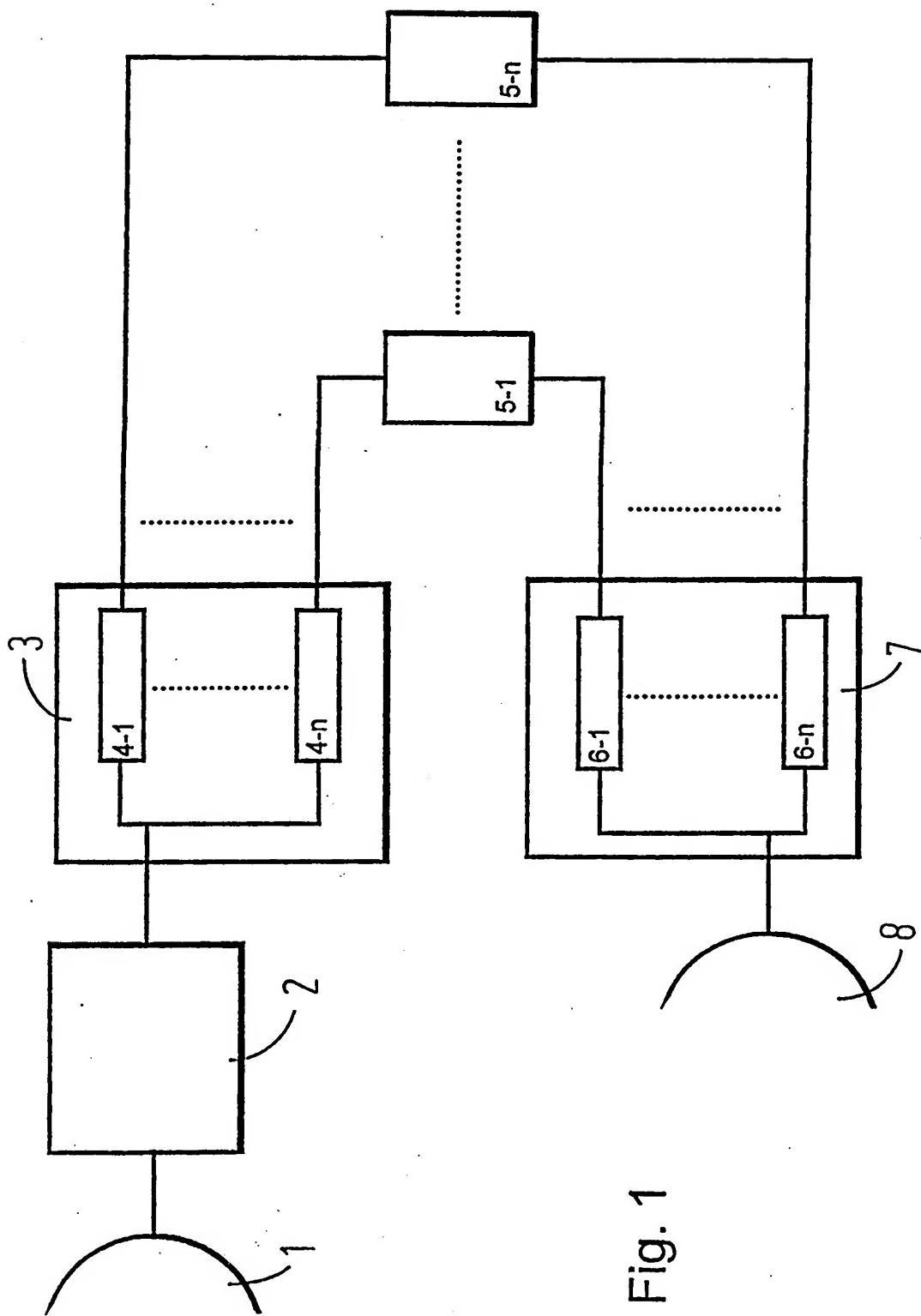
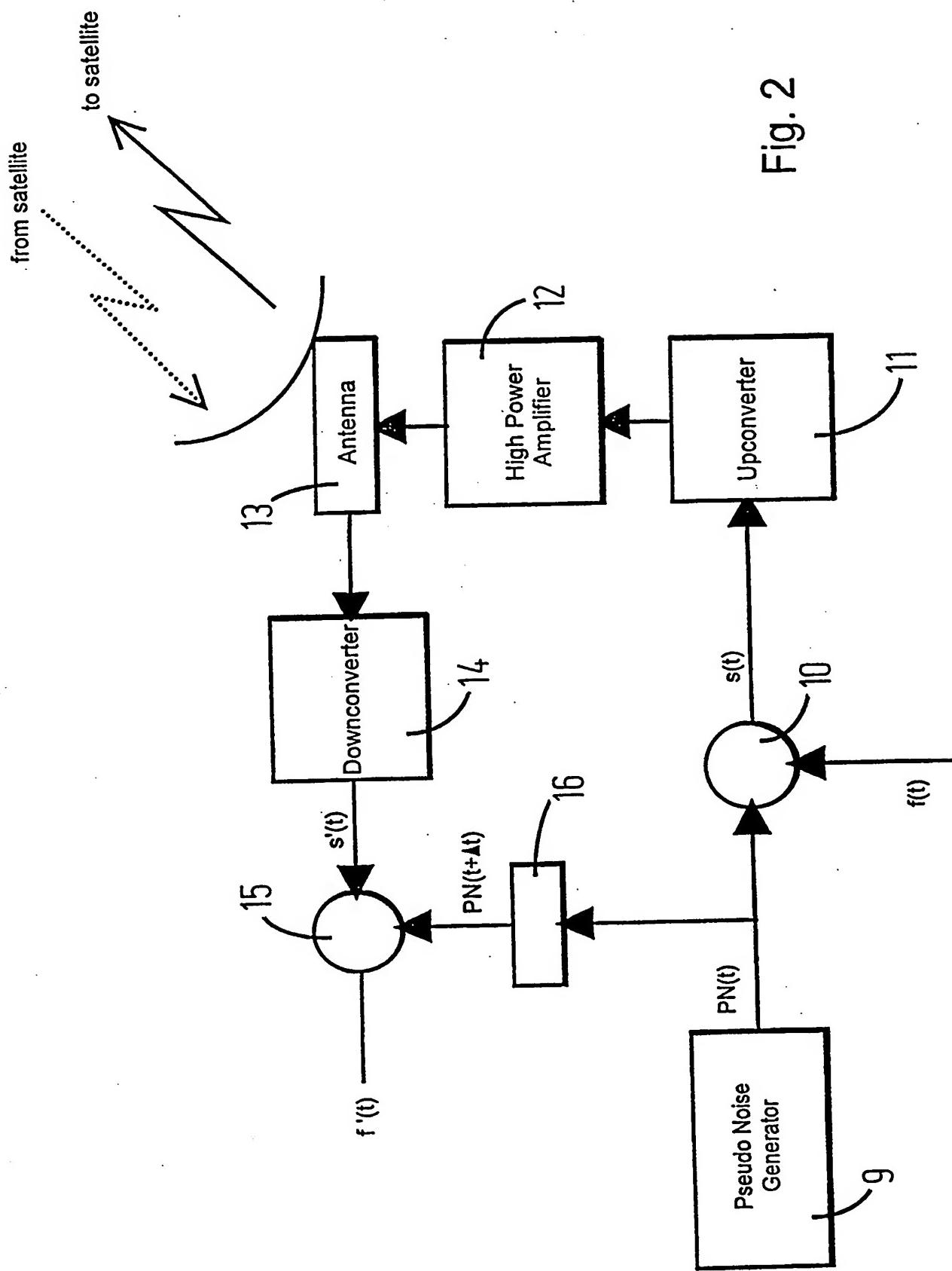


Fig. 1

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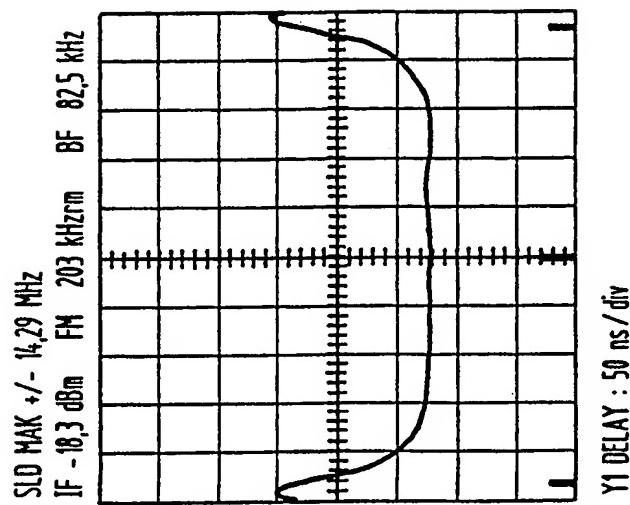


Fig. 3 b

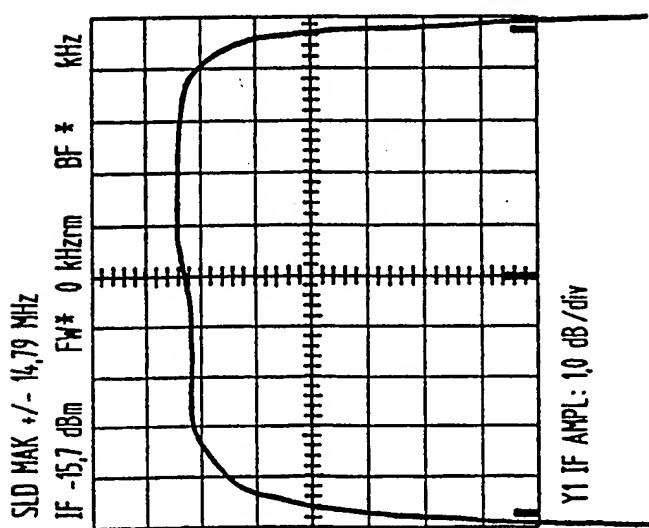


Fig. 3 a

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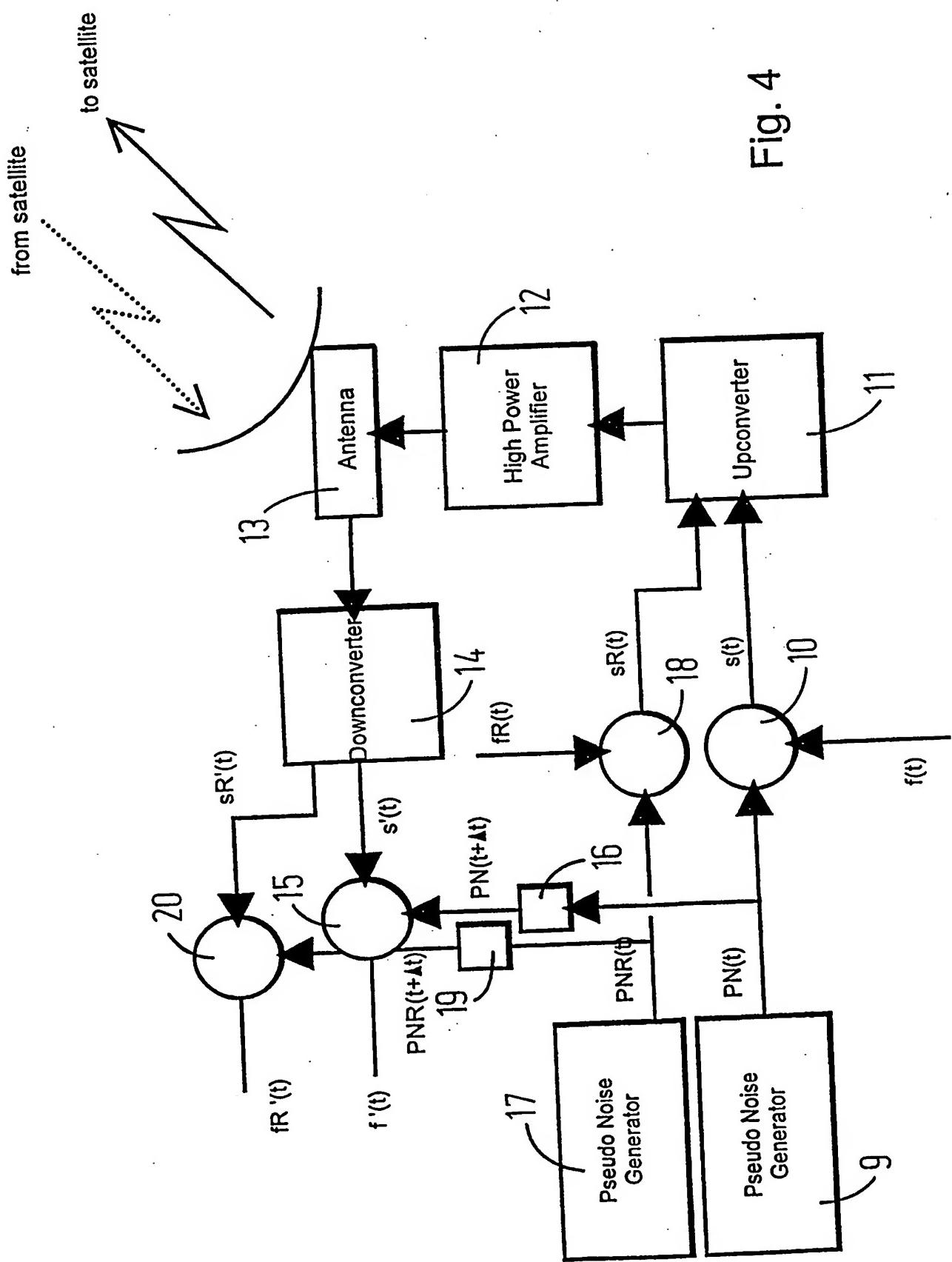


Fig. 4

INTERNATIONAL SEARCH REPORT

Int'l Application No
PCT/EP 98/08307

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04B17/00 H04B7/185

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the International search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 637 017 A (ASSAL FRANCOIS T ET AL) 13 January 1987 see abstract; claim 1	1,19
A	DE 36 44 175 A (MESSERSCHMITT BOELKOW BLOHM) 14 July 1988 see the whole document	1,19
A	EP 0 420 230 A (HUGHES AIRCRAFT CO) 3 April 1991 see abstract; claim 1; figure 1	1,19
A	US 5 036 523 A (BRISKMAN ROBERT D) 30 July 1991 see abstract; claim 1	1,19

Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

* Special categories of cited documents :

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- "O" document referring to an oral disclosure, use, exhibition or other means
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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

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Date of the actual completion of the International search

Date of mailing of the International search report

9 April 1999

26/04/1999

Name and mailing address of the ISA
European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl.
Fax: (+31-70) 340-3016

Authorized officer

Kolbe, W

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/EP 98/08307

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